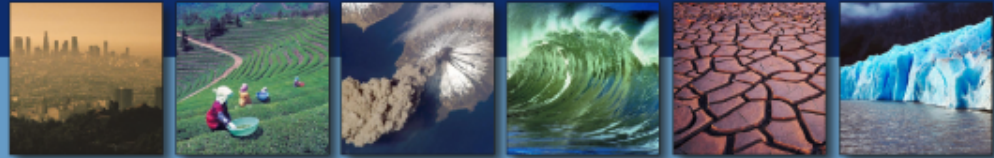


Phase-1 GEOGLAM Observation Strategy and Volumetric Assessment by the CEOS SEO

Brian Killough
SIT-28 Report
March 11, 2013
NASA LaRC, Hampton, VA, USA





| Region | Total Region Area (Mha) | Crop Area (Mha) | % Crops | Annual Cloud % in Croplands | Min Monthly Cloud % in Croplands | Max Monthly Cloud % in Croplands | Annual Precip (mm) | Min Monthly Precip in mm (Month) | Max Monthly Precip in mm (Month) |
|-----------|-------------------------|-----------------|---------|-----------------------------|----------------------------------|----------------------------------|--------------------|----------------------------------|----------------------------------|
| Australia | 768 | 22.0 | 3% | 60 | 53 (Jun) | 68 (Nov) | 534 | 18.1 (Sep) | 78.1 (Jan) |
| Argentina | 274 | 33.0 | 12% | 58 | 52 (Feb) | 65 (Jun) | 591 | 24.0 (Aug) | 63.5 (Mar) |
| Uganda | 20 | 2.5 | 13% | 65 | 49 (Jul) | 82 (Oct/Nov) | 1180 | 34.3 (Jan) | 148.9 (Apr) |
| Russia | 1689 | 44.5 | 3% | 75 | 53 (Aug) | 88 (Mar) | 460 | 16.1 (Feb) | 61.8 (Jul) |
| Ukraine | 58 | 22.0 | 38% | 71 | 48 (Jul) | 81 (Dec) | 565 | 29.7 (Mar) | 66.5 (Jul) |



| OBSERVATION & SENSOR TYPE | | | | |
|---------------------------|----------------------------|---|----------------|---|
| SPATIAL RES. | SPECTRAL RES. | TEMPORAL RES. | | |
| Spatial resolution | Spectral range | Effective observ. frequency (cloud free)* | Swath / Extent | Sample (s), Refined (rs) or Wall -to-Wall (w2w) |
| 500 - 2000 m | thermal IR + optical | few per day | global | w2w |
| 100-300 m | optical + SWIR | 2 to 5 per week | global | w2w |
| 1-15 km | passive microwave | daily | global | w2w |
| 50-150 m | SAR dual pol. (X,C,L) **** | 5 per season | main crops | s |
| 5-20m | SAR dual pol. (X,C,L) **** | 5 per season | main crops | s |
| Footprint | RADAR Altimetry | weekly | | s |
| 50-100m | thermal | daily ? | main crops | s |
| 20-70m | optical + SWIR | 1 per month (if possible same sensor) (min 2 out of season + 3 in season) | croplands | w2w |
| 20-70m | optical+SWIR | 1 per week (min. 1 per 2 weeks) | main crops | s |
| 5-10 m | optical (+SWIR)*** | 1 per month (if possible same sensor) (min 2 out of season + 3 in season) | croplands | rs |
| 5-10 m | optical (+SWIR)*** | 1 per week (min. 1 per 2 weeks) | main crops | rs2 |
| < 5 m | optical | 1 to 2 per month | croplands | rs3 |

Mixture of Optical (low to high resolution) and SAR.

Temporal sampling varies from daily to seasonal.

Spatial sampling varies from wall-to-wall to small-scale cropland samples.



Global Coverage - Optical Low-Resolution (>100m)

| Mission | Instrument | Bands | Launch |
|-------------|------------|-----------------------|----------|
| Terra | MODIS | VIS,NIR,SWIR,MWIR,TIR | Dec 1999 |
| Aqua | MODIS | VIS,NIR,SWIR,MWIR,TIR | May 2002 |
| SPOT-5 | Vegetation | VIS,NIR,SWIR | May 2002 |
| FY-1D | MVISR | VNIR,MWIR,SWIR,TIR | May 2002 |
| FY-3A | MERSI/VIRR | VIS,NIR,SWIR,MWIR,TIR | May 2008 |
| HJ-1B | IRMSS | NIR,SWIR,MWIR,TIR | Sep 2008 |
| FY-3B | MERSI/VIRR | VIS,NIR,SWIR,MWIR,TIR | Nov 2010 |
| NPP | VIIRS | VIS,NIR,SWIR,MWIR,TIR | Oct 2011 |
| Proba-V | VGT-P | VNIR,SWIR | Apr 2013 |
| Sentinel-3A | SLSTR | VNIR,SWIR,TIR | Apr 2014 |

Country Sampling - Optical High-Resolution (<10m)

| Mission | Instrument | Bands | Launch |
|---------------|--------------|---------------|----------|
| IKONOS-2 | OSA | VIS, NIR, PAN | Sep 1999 |
| SPOT-5 | HRG | VIS,NIR,SWIR | May 2002 |
| GeoEye-1 | GIS | VIS, NIR, PAN | Sep 2008 |
| RapidEye | REIS | VIS,NIR | Aug 2008 |
| WorldView-2 | WV110 | VIS, NIR, PAN | Oct 2009 |
| ResourceSat-2 | LISS-4 (SMX) | VIS,NIR | Apr 2011 |
| Pleiades-1A | HiRI | VIS,NIR | Dec 2011 |
| Pleiades-1B | HiRI | VIS,NIR | Dec 2012 |
| GeoEye-2 | GIS | VIS, NIR, PAN | Mar 2013 |
| CBERS-3 | PanMUX | VIS, NIR, PAN | Apr 2013 |

**Country Coverage (Wall-to-Wall) and Country Sampling
Optical Mid-resolution (10m to 100m)**

| Mission | Instrument | Bands | Launch |
|---------------|------------|------------------|----------|
| Landsat-7 | ETM+ | VIS,PAN,SWIR,TIR | Apr 1999 |
| Terra | ASTER | VNIR,SWIR,TIR | Dec 1999 |
| HJ-1A & 1B | WVC | VIS,NIR | Sep 2008 |
| HJ-1A | HSI | VIS,NIR | Sep 2008 |
| Deimos-1 | SLIM-6 | VIS,IR | Jul 2009 |
| ResourceSat-2 | LISS-3 | VIS,NIR,SWIR | Apr 2011 |
| ResourceSat-2 | AWiFS | VIS,NIR,SWIR | Apr 2011 |
| LDCM | OLI + TIRS | PAN,VIS,SWIR,TIR | Feb 2013 |
| CBERS-3 | WFI-2 | VIS,NIR | Apr 2013 |
| CBERS-3 | MUXCam | VIS | Apr 2013 |
| CBERS-3 | IRMSS | PAN,SWIR,TIR | Apr 2013 |
| Sentinel-2A | MSI | VNIR,SWIR | Jun 2014 |
| Sentinel-2B | MSI | VNIR,SWIR | May 2015 |

These tables represent **candidate** GEOGLAM missions.

Highlighted missions are restricted (for fee) datasets.



GEOGLAM countries for Phase-1

- Australia, Argentina, Russia, Ukraine + Uganda

GEOGLAM Missions and Instruments (primary)

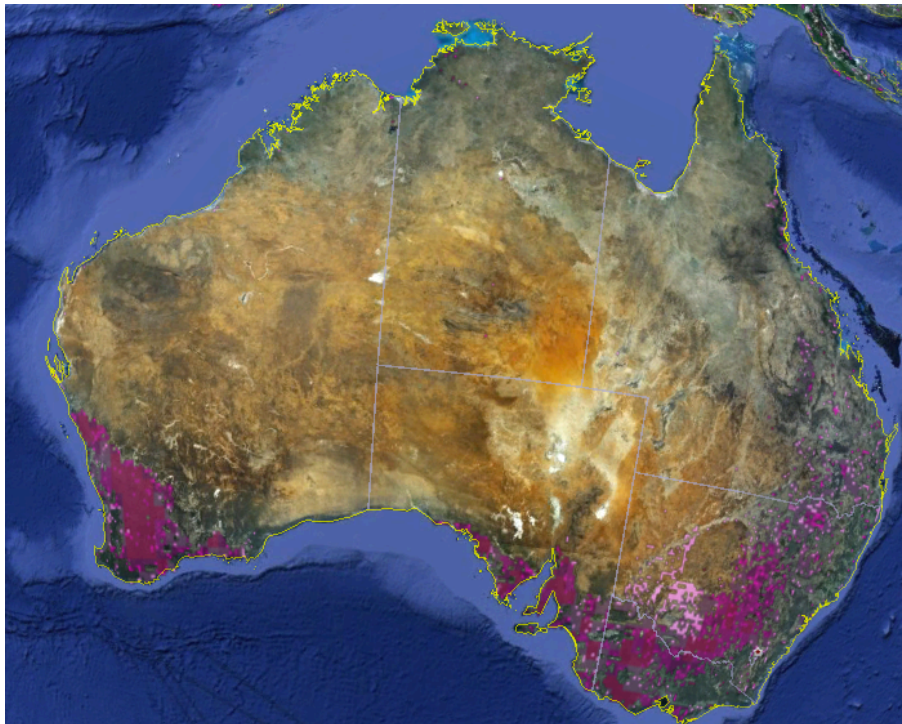
- Low-Resolution = Terra (MODIS), Aqua (MODIS), NPP (VIIRS), Spot-5 (Vegetation)
- Mid-Resolution = Landsat-7 (ETM+), LDCM (OLI,TIRS), ResourceSat-2 (LISS-3, AWIFS)
- High-Resolution = SPOT-5 (HRG), RapidEye (REIS), Pleiades-1A/1B (HIRI)

GEOGLAM will need to coordinate with the following agencies for access to datasets:

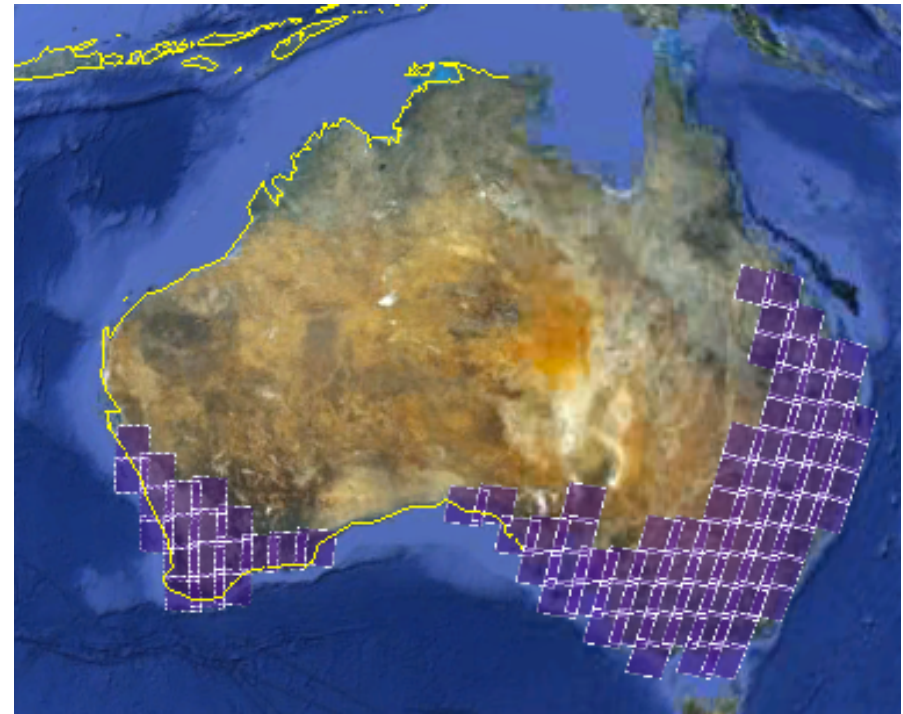
***ISRO** - ResourceSat-2, **CNES** - SPOT-5 and Pleiades, **CSA and DLR** - RapidEye.*

Temporal Sampling

- Low Resolution - Weekly (daily possible with minor gaps) wall-to-wall
- Mid Resolution – Monthly (during growing season) wall-to-wall
- High Resolution – Monthly (coincident with monthly mid-resolution sampling)



Crop Mask (wheat)



Landsat Scenes = 54



| Mission | Instrument | Total Paths | Total Duration of Acquisitions (min) | Total Scenes | Total Data Volume (GB) |
|---------------|------------|-------------|--------------------------------------|--------------|------------------------|
| Terra | MODIS | 1 | 3.9 | 176 | 0.30 |
| Aqua | MODIS | 1 | 3.9 | 176 | 0.30 |
| SPOT-5 | Vegetation | 1 | 6.6 | 295 | 0.53 |
| NPP | VIIRS | 1 | 7.1 | 270 | 0.55 |
| | | | | | |
| Landsat 7 | ETM+ | 9 | 20.4 | 54 | 22.41 |
| LDCM | OLI + TIRS | 9 | 20.4 | 54 | 22.41 |
| Resourcesat-2 | LISS -III | 12 | 52.1 | 166 | 20.02 |
| Resourcesat-2 | AWIFS | 2 | 9.1 | 11 | 3.51 |
| CBERS-3 | WFI-2 | 2 | 13.7 | 51 | 5.31 |



Crop Mask:

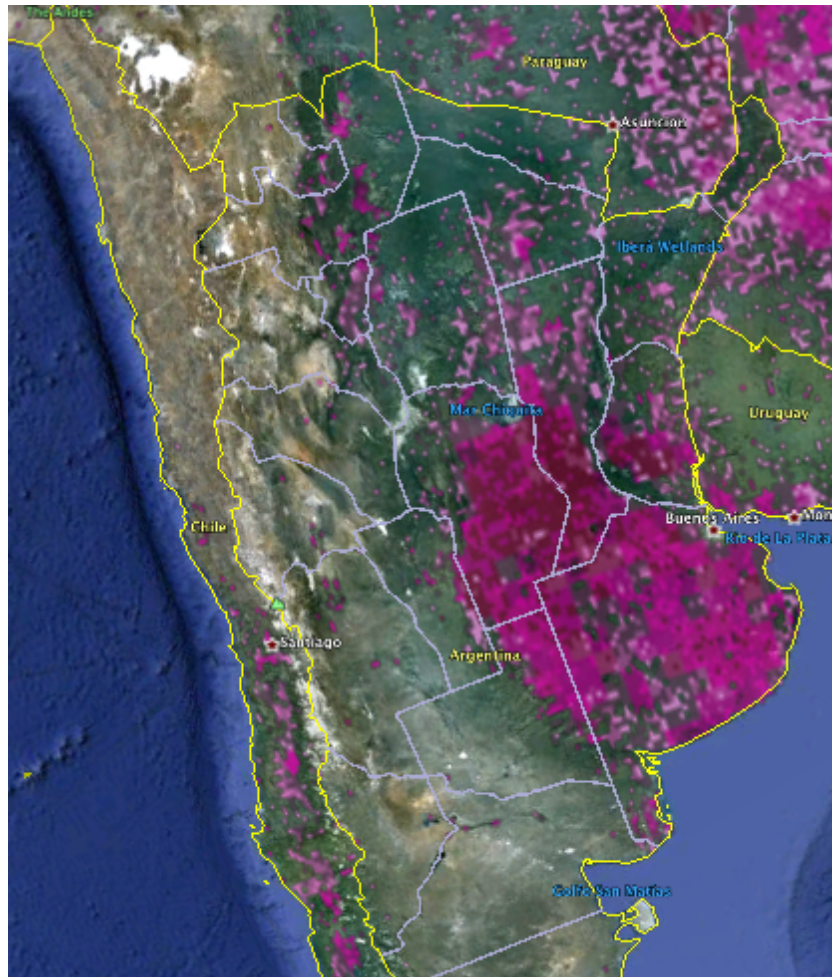
Maize, millet, sorghum, cassava, beans, sweet potatoes, groundnuts



Landsat Scenes = 15



| Mission | Instrument | Total Paths | Total Duration of Acquisitions (min) | Total Scenes | Total Data Volume (GB) |
|---------------|------------|-------------|--------------------------------------|--------------|------------------------|
| Terra | MODIS | 1 | 0.2 | 10 | 0.02 |
| Aqua | MODIS | 1 | 0.2 | 10 | 0.02 |
| SPOT-5 | Vegetation | 1 | 1.5 | 69 | 0.12 |
| NPP | VIIRS | 1 | 1.2 | 47 | 0.10 |
| | | | | | |
| Landsat 7 | ETM+ | 9 | 5.7 | 15 | 6.23 |
| LDCM | OLI + TIRS | 9 | 5.7 | 15 | 6.23 |
| Resourcesat-2 | LISS -III | 12 | 6.9 | 22 | 2.65 |
| Resourcesat-2 | AWIFS | 2 | 3.3 | 4 | 1.27 |
| CBERS-3 | WFI-2 | 2 | 2.4 | 9 | 0.94 |



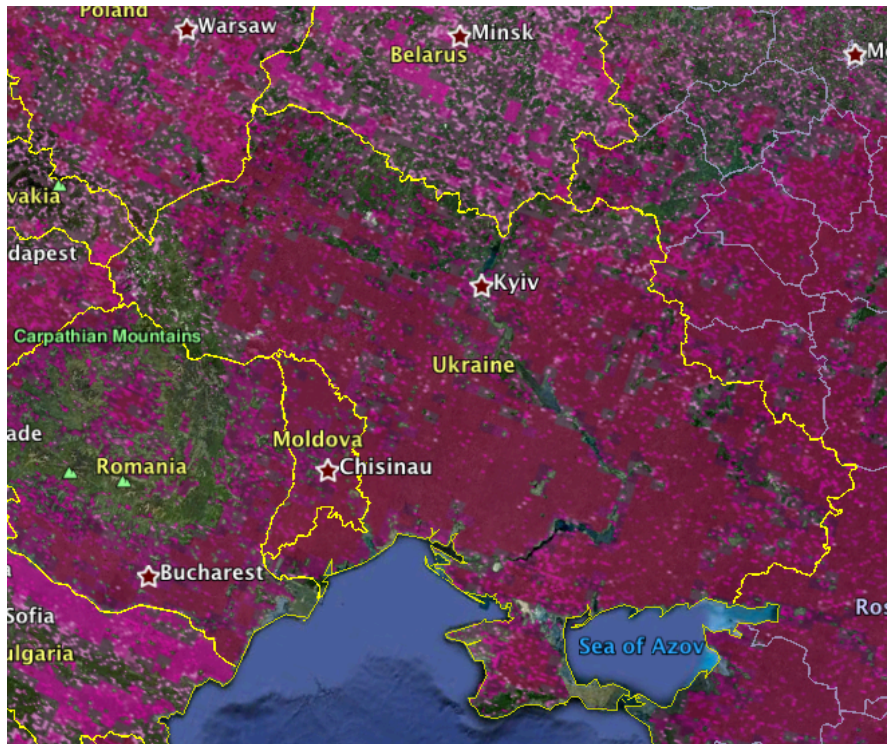
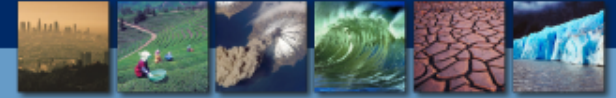
Crop Mask: Soy, Wheat, Corn



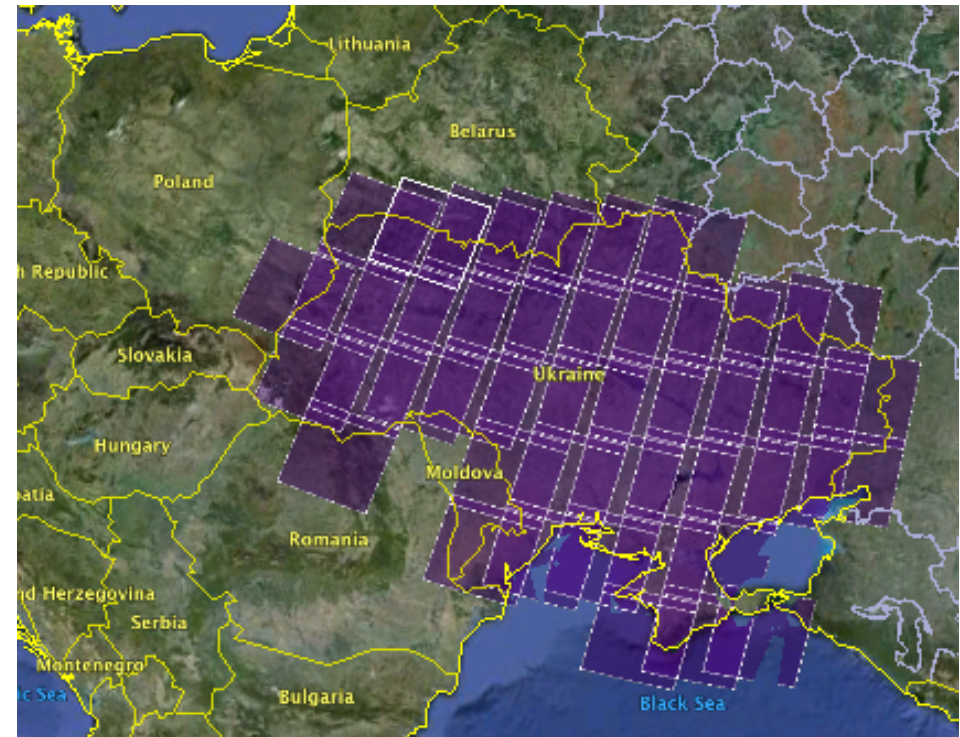
Landsat Scenes = 78



| Mission | Instrument | Total Paths | Total Duration of Acquisitions (min) | Total Scenes | Total Data Volume (GB) |
|---------------|------------|-------------|--------------------------------------|--------------|------------------------|
| Terra | MODIS | 1 | 4.7 | 211 | 0.36 |
| Aqua | MODIS | 1 | 4.7 | 211 | 0.36 |
| SPOT-5 | Vegetation | 1 | 4.9 | 218 | 0.39 |
| NPP | VIIRS | 1 | 4.7 | 177 | 0.36 |
| | | | | | |
| Landsat 7 | ETM+ | 9 | 29.5 | 78 | 32.37 |
| LDCM | OLI + TIRS | 9 | 29.5 | 78 | 32.37 |
| Resourcesat-2 | LISS -III | 12 | 43.9 | 140 | 16.88 |
| Resourcesat-2 | AWIFS | 2 | 9.1 | 11 | 3.51 |
| CBERS-3 | WFI-2 | 2 | 8.6 | 32 | 3.33 |



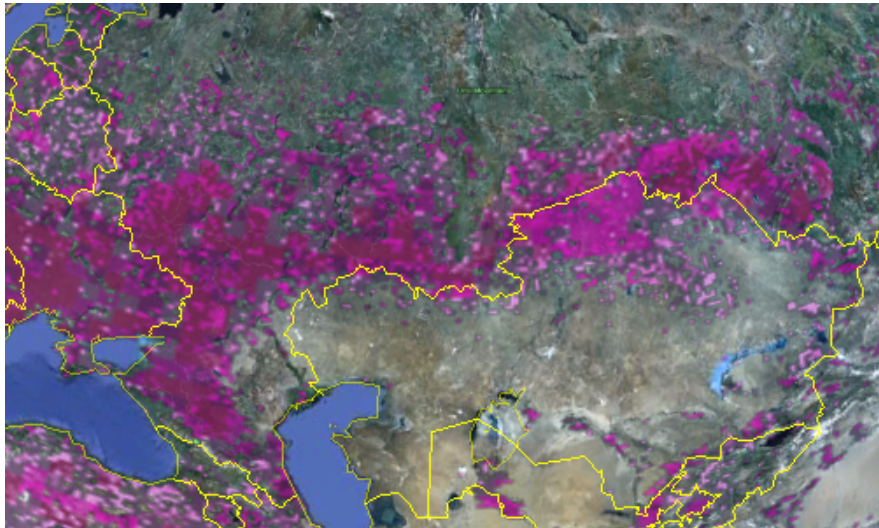
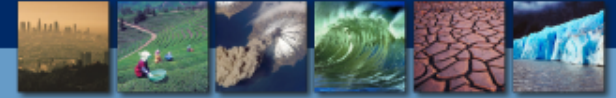
Crop Mask (wheat, corn)



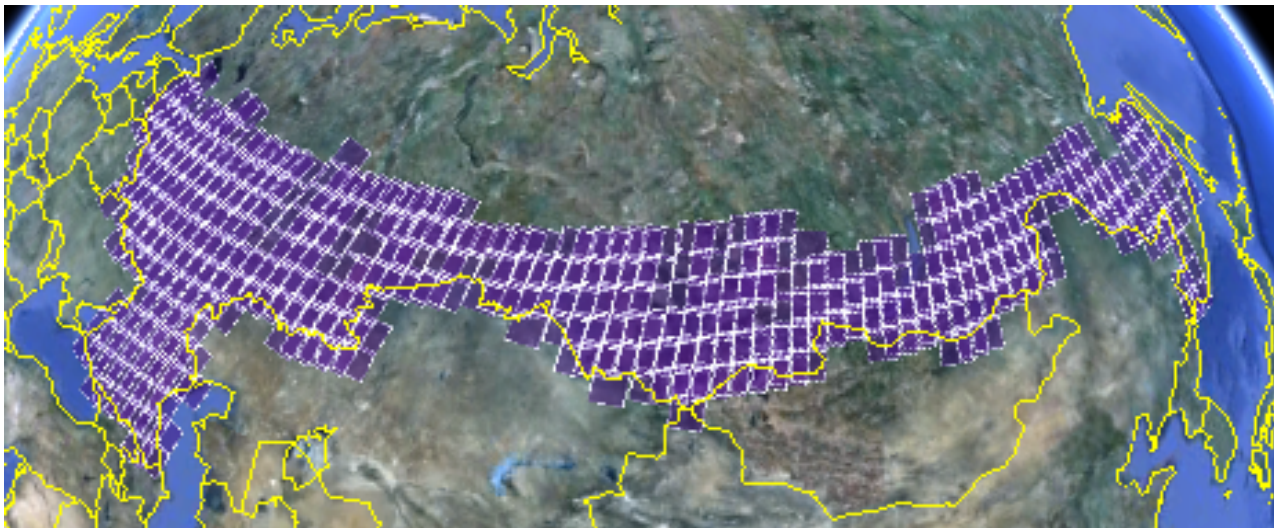
Landsat Scenes = 45



| Mission | Instrument | Total Paths | Total Duration of Acquisitions (min) | Total Scenes | Total Data Volume (GB) |
|---------------|------------|-------------|--------------------------------------|--------------|------------------------|
| Terra | MODIS | 1 | 2.4 | 106 | 0.18 |
| Aqua | MODIS | 1 | 2.4 | 106 | 0.18 |
| SPOT-5 | Vegetation | 1 | 2.0 | 91 | 0.16 |
| NPP | VIIRS | 1 | 2.3 | 87 | 0.18 |
| | | | | | |
| Landsat 7 | ETM+ | 9 | 17.0 | 45 | 18.68 |
| LDCM | OLI + TIRS | 9 | 17.0 | 45 | 18.68 |
| Resourcesat-2 | AWIFS | 12 | 24.8 | 79 | 9.53 |
| Resourcesat-2 | LISS -III | 2 | 5.8 | 7 | 2.23 |
| CBERS-3 | WFI-2 | 2 | 3.8 | 14 | 1.46 |



Crop Mask
(wheat, corn)



Landsat
Scenes = 382



| Mission | Instrument | Total Paths | Total Duration of Acquisitions (min) | Total Scenes | Total Data Volume (GB) |
|---------------|------------|-------------|--------------------------------------|--------------|------------------------|
| Terra | MODIS | 1 | 7.8 | 350 | 0.60 |
| Aqua | MODIS | 1 | 7.8 | 350 | 0.60 |
| SPOT-5 | Vegetation | 1 | 15.2 | 680 | 1.23 |
| NPP | VIIRS | 1 | 13.1 | 494 | 1.00 |
| | | | | | |
| Landsat 7 | ETM+ | 9 | 144.3 | 382 | 158.54 |
| LDCM | OLI + TIRS | 9 | 144.3 | 382 | 158.54 |
| Resourcesat-2 | LISS -III | 12 | 167.5 | 534 | 64.40 |
| Resourcesat-2 | AWIFS | 2 | 33.2 | 40 | 12.75 |
| CBERS-3 | WFI-2 | 2 | 35.7 | 133 | 13.84 |



| Mission | Passes / Scenes for each GEOGLAM Country | | | | |
|----------------------|--|-----------|-----------|---------|---------|
| | Argentina | Australia | Russia | Uganda | Ukraine |
| Spot 5 HRG | 26/806 | 50/1650 | 122/5002 | 12/132 | 21/399 |
| RapidEye REIS | 20/1500 | 39/3042 | 94/9212 | 10/260 | 16/704 |
| Pleiades-1A& 1B HIRI | 74/6882 | 147/14406 | 364/44408 | 34/1088 | 59/3245 |

- This table represents the total number of passes/scenes required to cover the entire agriculture region. This is NOT representative of the actual required measurements, but bounds the problem at the highest level.
- Each of these mission-instrument combinations is restricted and only available for a fee. GEOGLAM will need to coordinate with agencies to obtain some sample datasets for evaluation in the early phases of GEOGLAM.
- It is anticipated that GEOGLAM will define the sampling strategy and exact locations within each region in 2013.



GFOI = Global Forest Observation Initiative

- Forest and agriculture regions within any country are NOT the same.
- Wall-to-wall optical coverage is the likely synergy for acquisitions.
- GFOI country list includes FCT, REDD+ and UN-REDD = **44 total**. GEOGLAM country list includes 21 “producers” and 5+ “at risk” countries = **26+ total**.
- There are **6 “producer” countries and 1 “at-risk” country** that are common between GFOI and GEOGLAM. These include Argentina, Australia, Brazil, Paraguay, Thailand, Vietnam, and Uganda (at-risk).